NOAA's Colorado Basin River Forecast Center

Incorporation of a Stochastic Weather Generator to Further Inform Ensemble Streamflow Prediction in the Colorado River Basin

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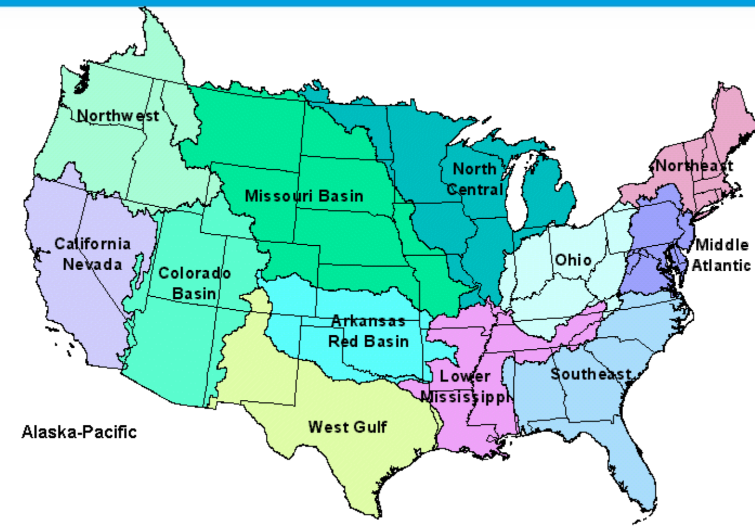
Special Thanks To…

- Andrew Verdin
  - University of Colorado
  - Development of Stochastic Weather Generator
  - Ph. D. examined application of SWG in Argentina
- Janelle Hakala
  - 2016 NOAA Hollings Scholar
  - Senior at the University of North Dakota
  - Volunteer position with Grand Forks, ND Weather Forecast Office

Who Are We?



- Part of NOAA - NWS, one of 13 RFCs nationwide
- An operational field office located in Salt Lake City, UT
- Highly collaborative, reliant on partners and data
- All about decision-support!

Who We Are

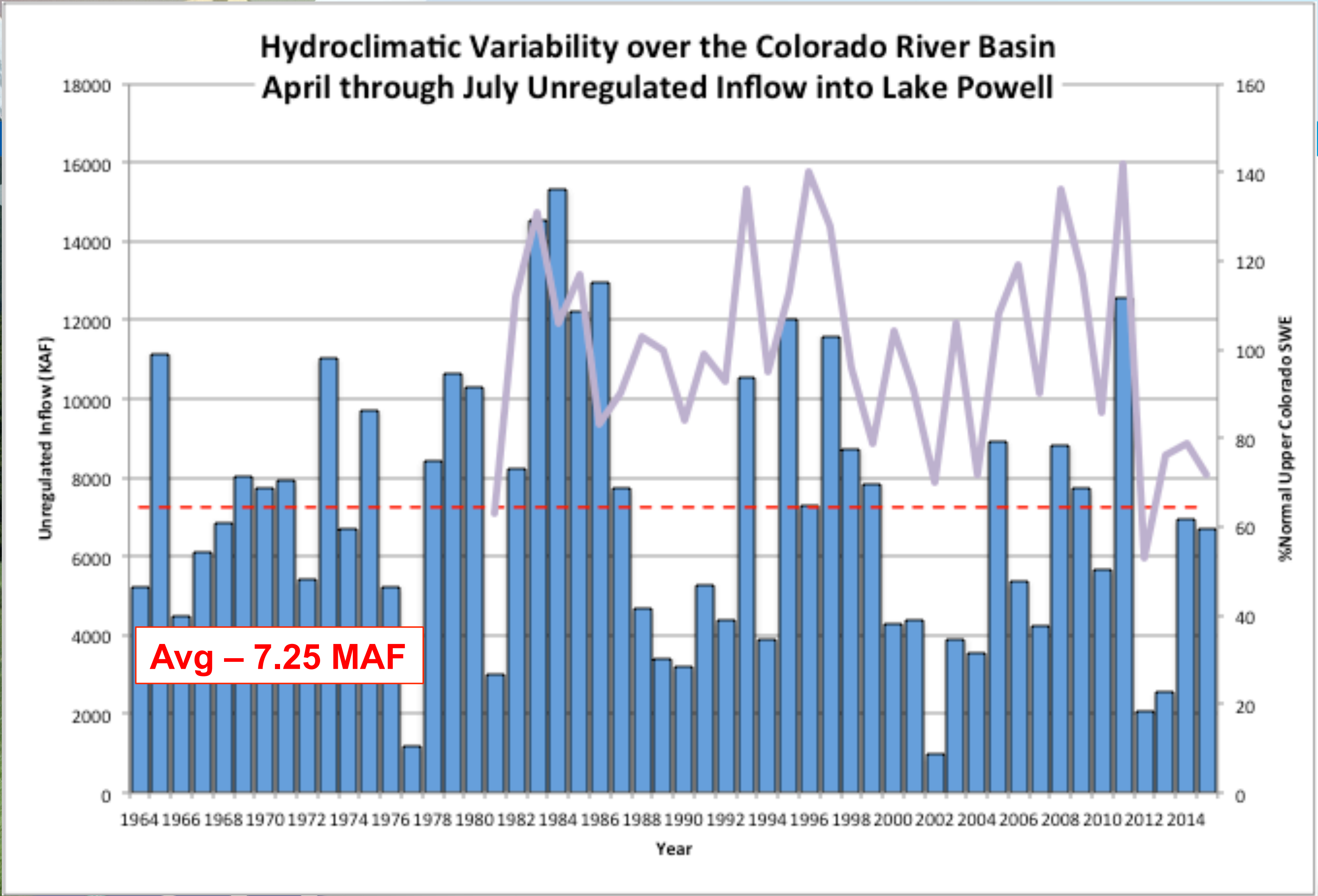
- Work with a broad and diverse set of stakeholders
  - Weather Forecast Offices and Reclamation
  - Municipal and Agricultural Water Users
  - USGS, NRCS, and many other federal agencies
  - State agencies, Academics, NGOs, Tribes
- Receive data from many of these sources

Colorado Basin River Forecast Center

- River Forecast Centers (RFCs)
  - Support for WFOs
  - River levels and flows
  - Reservoir inflows
  - Each RFC is unique
- CBRFC
  - Seasonal Water Supply forecasts, in addition to many other products
    - Most advanced, involved
    - Reclamation is a key stakeholder
    - www.cbrfc.noaa.gov

Weather Forecast Offices (WFOs)

- **Everyday weather**
- **Extreme weather**
  - **Warnings, watches, and advisories**
  - **Floods, tornadoes, heat, etc…**

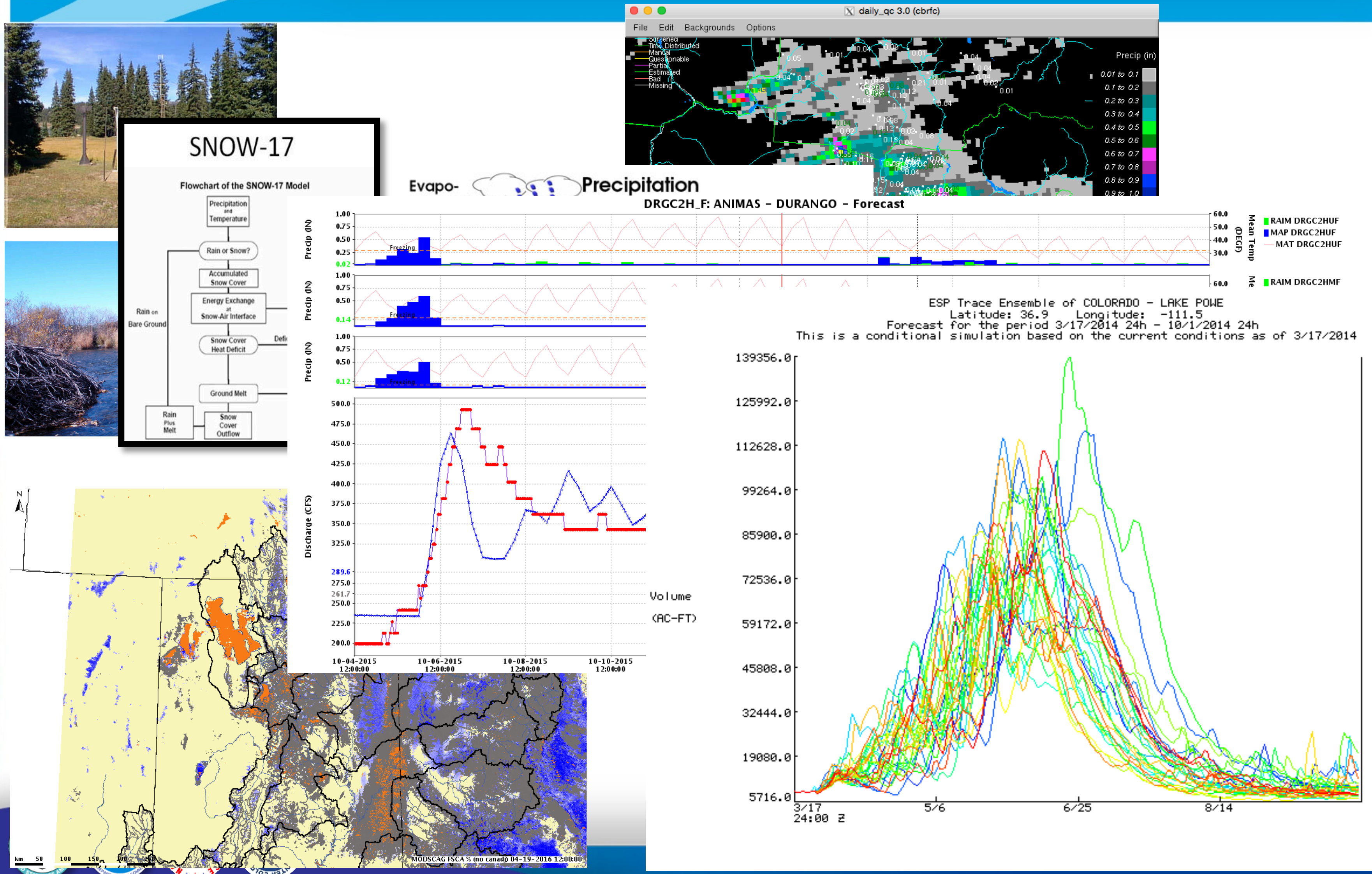


Hydroclimatic Variability over the Colorado River Basin
April through July Unregulated Inflow into Lake Powell
Unregulated Inflow (KAF)
%Normal Upper Colorado SWE
Year
Avg – 7.25 MAF
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
20
40
60
80
100
120
140
160
1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014

Products and Services

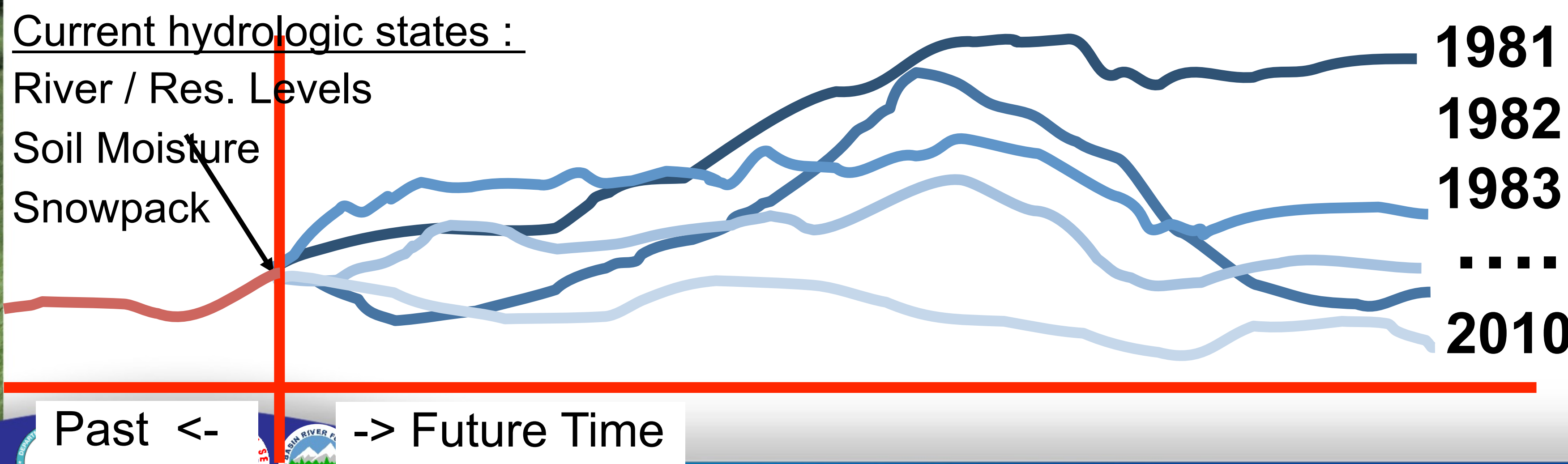
- Water Supply Forecast
  - Utilize an ensemble of past climate to generate possible streamflow futures (1981 – 2010)
  - Dependent on precipitation information during the runoff season – we pay close attention to snowpack
  - Model soil moisture component is very important
- The more information we have the better!

Generating Ensemble Forecasts



ESP Probabilistic Forecasts

- Start with current conditions (from the daily model run)
- Apply precipitation and temperature from each historical year (1981-2010)
- A forecast is generated for each of the years (1981-2010) *as if, going forward,* that year will happen
- This creates 30 possible future streamflow patterns. Each year is given a 1/30 chance of occurring



We Know The Climate Is Changing

Temperatures are rising and will continue to rise

Precipitation outlook is uncertain, but we do expect more extreme events

Decreased water supply, particularly for the Southwest and Colorado River Basin

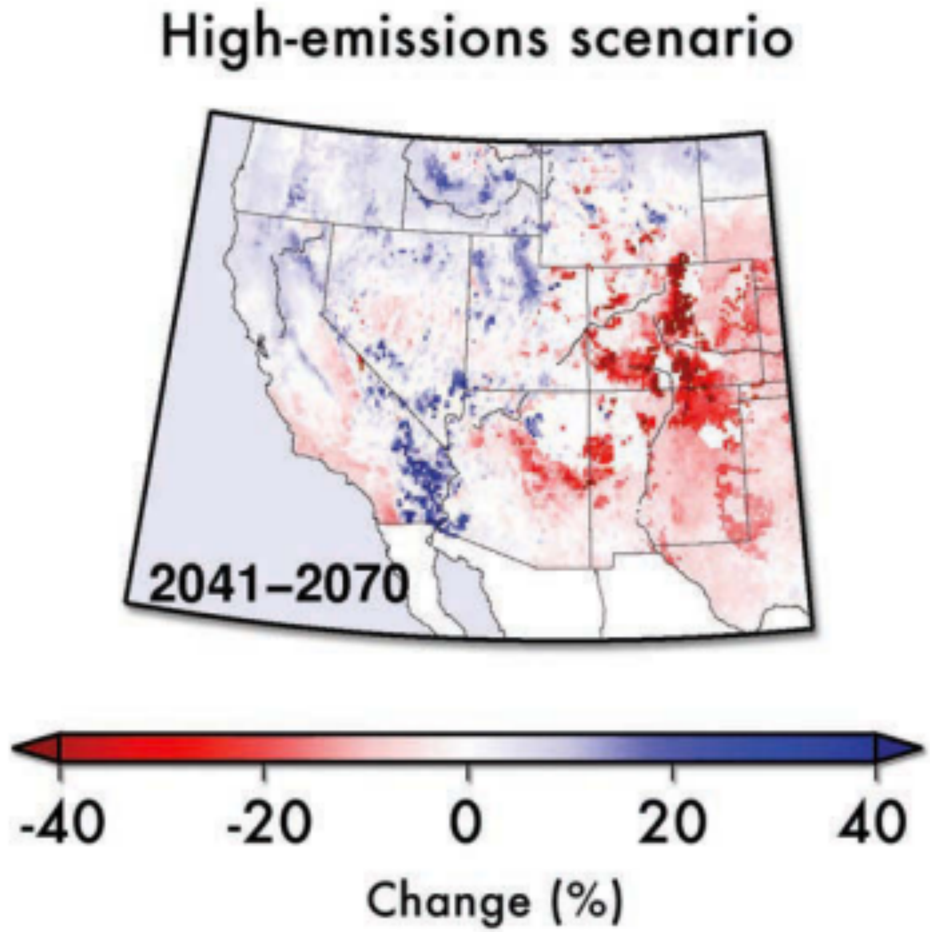


Figure from: Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy, eds. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

And Our Stakeholder's Needs Are Changing

- Where we were:
  - What is THE forecast?
  - How much water is there?
  - How much snow is there?
  - Will there be flooding?
- Where we are going:
  - What is the range of forecasts?
  - What is the likelihood of reaching this flow?
  - What if it's a dry/wet year?
  - What is the risk to filling my reservoir?
  - What is your uncertainty?

Challenges Ahead

- Climate Change and its Impacts
  - Stationarity is in the past – but it's also how we look forward
  - Extreme Events – persistent drought and intense rains can impact our forecasts, and our stakeholder's ability to manage resources effectively
  - Is there a way to leverage climate information into our water supply forecasts?

Moving Forward

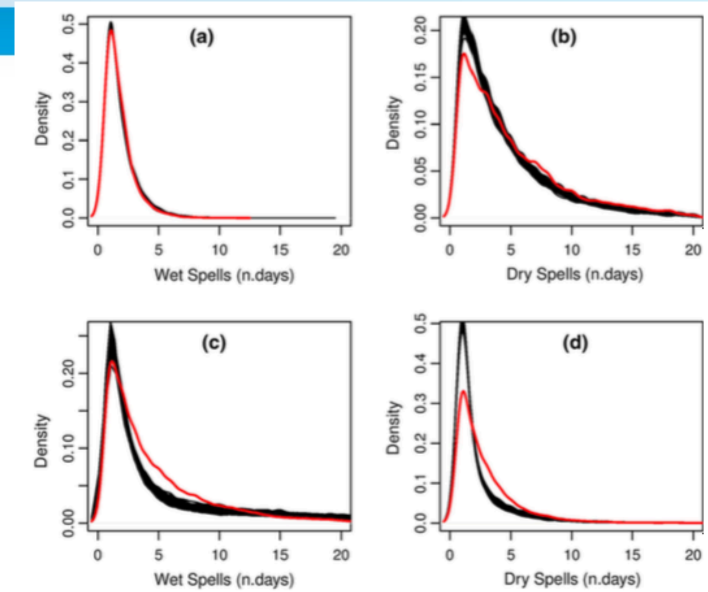
- Investigating the use of a Stochastic Weather Generator
  - Reduce reliance on historical weather and climate
  - Understand variability and risk better
  - Incorporate climate information

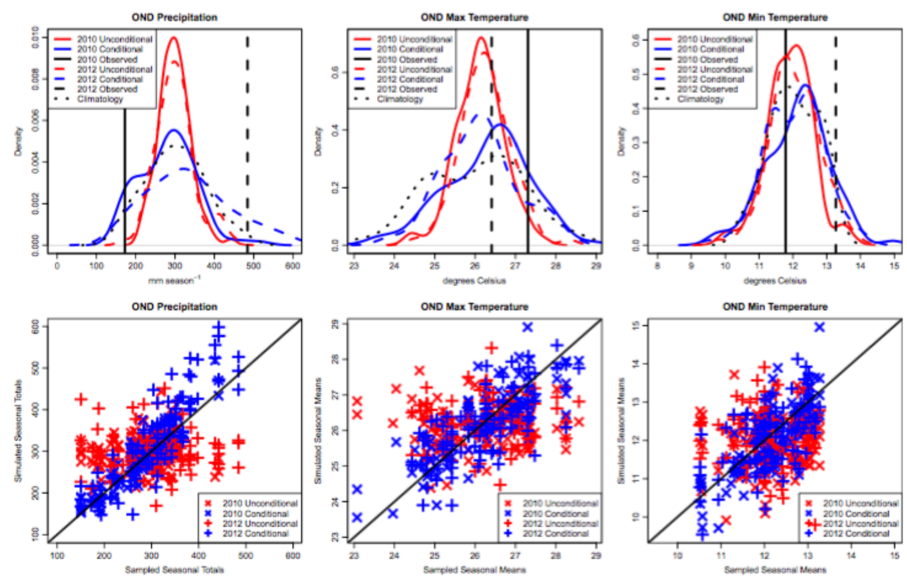
Stochastic Weather Generator

- Developed at the University of Colorado
- Nonparametric
  - Utilizes a k-NN approach
  - Daily weather is simulated using a generalized linear model
- Spatially consistent (based on historical data)
- Incorporate climate information

Stochastic Weather Generator

- See Verdin et al., 2015 in Stochastic Environmental Research and Risk Assessment
- And Verdin et al., 2015 in Journal of Hydrology



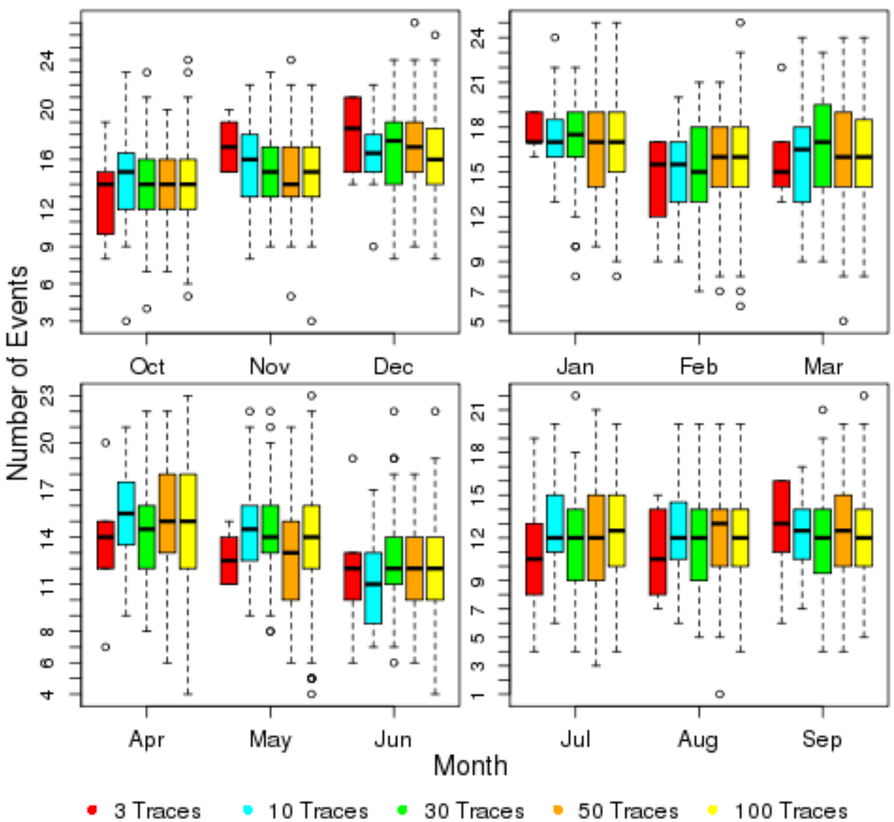


Initial Results

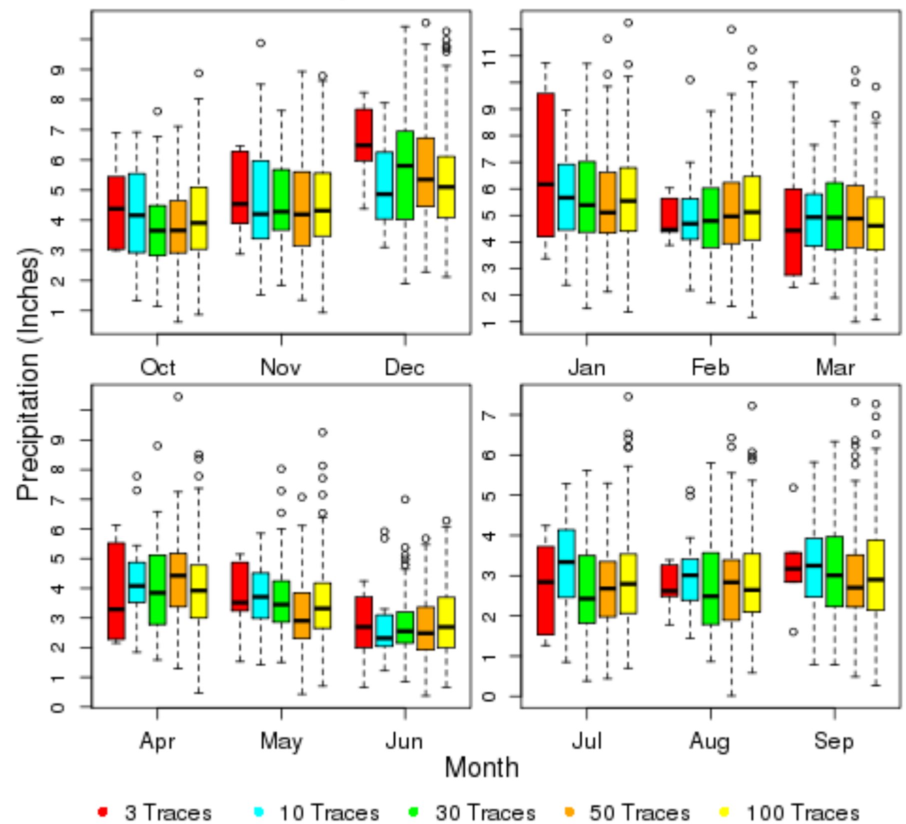
- Unconditioned Results
  - No climate information as of yet
  - Partially answers: "Are 30 traces enough to capture hydroclimatic variability?"
- Gunnison River Basin – East River at Almont
- Capturing much of the precipitation and temperature variability at 30 traces

Initial Results

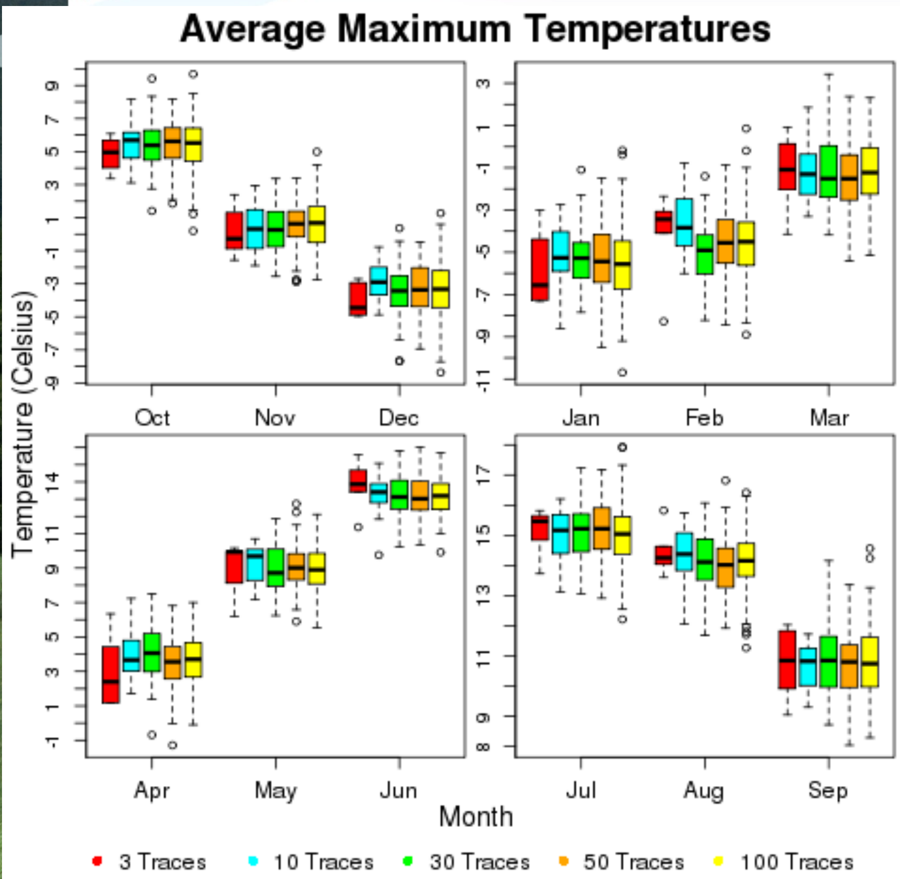
Monthly Precipitation Occurrence

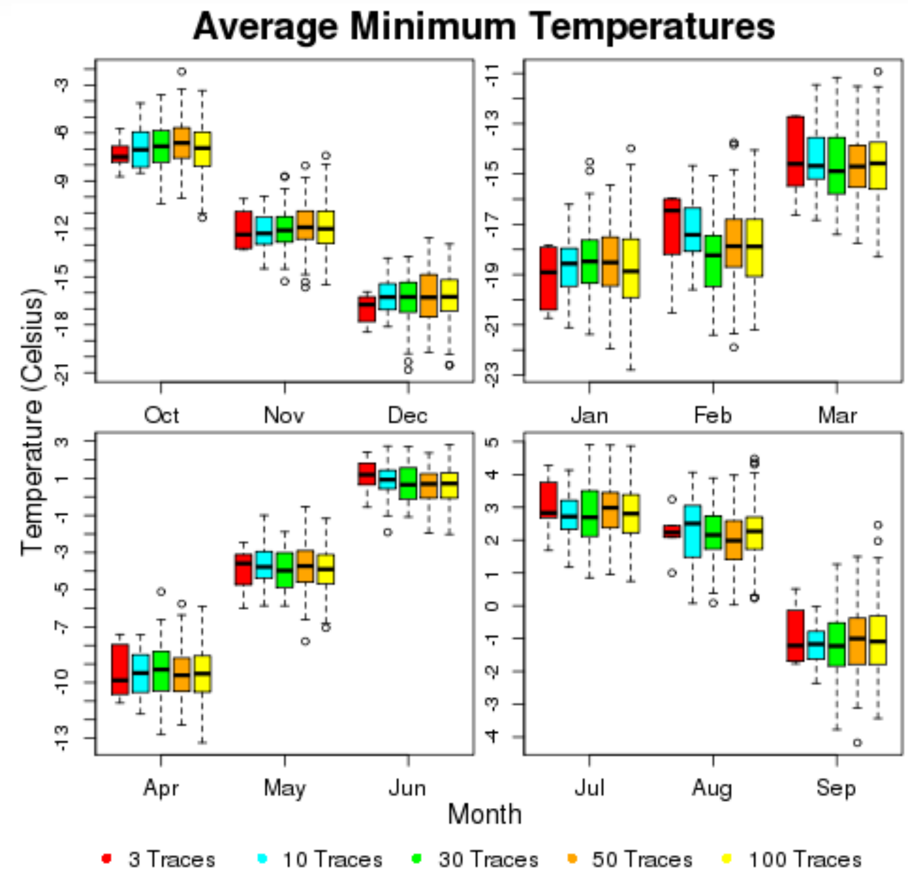


Monthly Precipitation Amount



Initial Results



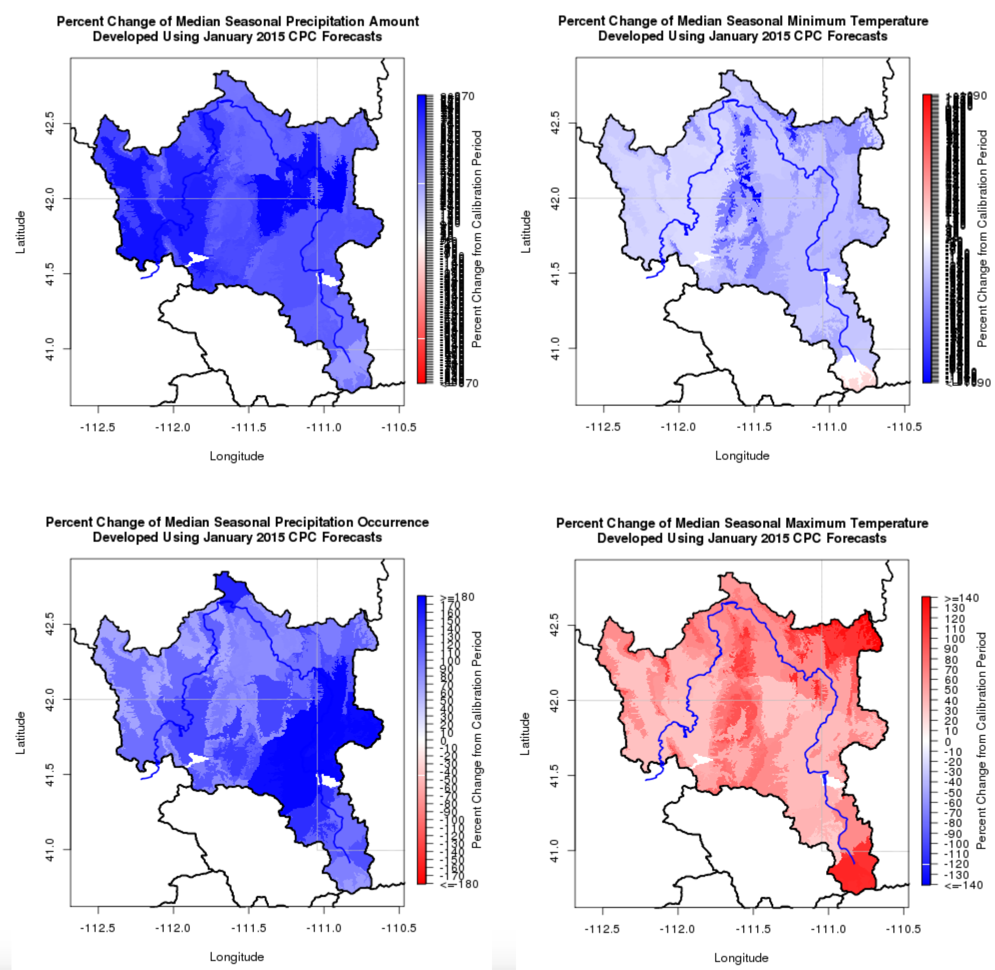


Initial Results

- Conditional Results
  - Based on CPC probabilities in the Upper Bear River Basin
  - Currently, there is a slight coding error causing some unreasonable results
  - Ability to develop spatial results is encouraging

Initial Results

- Results are currently unreasonable, but show the ability to generate spatially consistent ensembles over a broad area
- Error can be fixed!



Next Steps

- Fix coding error
- Utilize CPC values more robustly to weight SWG
- Use derived weather scenarios to generate hydrologic scenarios
- Verify with historical runs

Questions?

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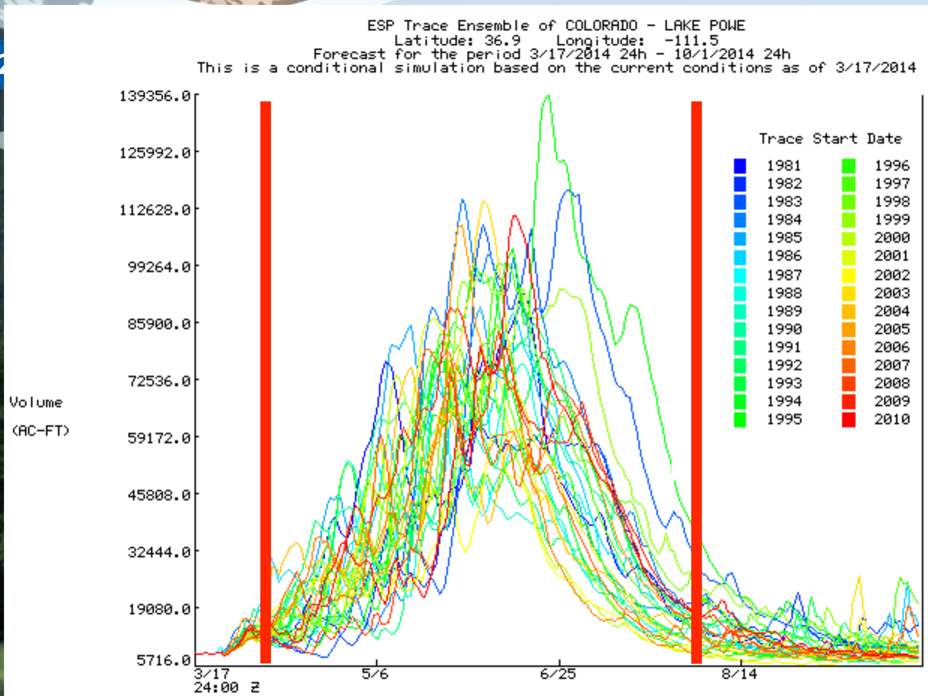
Extra Slides

ESP Probabilistic Forecasts



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\# EMPIRICAL SAMPLE POINTS

#Trace year	Cond. Year Weight	Data Point	Exceed. Prob.
1981	0.033	10583427.0	0.290
1982	0.033	8372498.00	0.806
1983	0.033	12646544.0	0.065
1984	0.033	11904022.0	0.129
1985	0.033	11402967.0	0.161
1986	0.033	10406237.0	0.355
1987	0.033	8369501.00	0.839
1988	0.033	8719326.00	0.742
1989	0.033	7605042.50	0.935
1990	0.033	9761623.00	0.452
1991	0.033	9690117.00	0.484
1992	0.033	9298360.00	0.613
1993	0.033	10987106.0	0.226
1994	0.033	9395003.00	0.548
1995	0.033	14388755.0	0.032
1996	0.033	8611564.00	0.774
1997	0.033	10736442.0	0.258
1998	0.033	10159611.0	0.419
1999	0.033	12520652.0	0.097
2000	0.033	8252478.50	0.871
2001	0.033	9312369.00	0.581
2002	0.033	6439105.00	0.968
2003	0.033	9439112.00	0.516
2004	0.033	8867351.00	0.710
2005	0.033	10415361.0	0.323
2006	0.033	8235550.00	0.903
2007	0.033	8964843.00	0.645
2008	0.033	8954274.00	0.677
2009	0.033	11320183.0	0.194
2010	0.033	10185848.0	0.387

2

# Exceedance Probabilities	Conditional Simulation
0.900	8237243.000
0.800	8420311.000
0.700	8893428.000
0.600	9303964.000
0.500	9564614.000
0.400	10175353.000
0.300	10533006.000
0.200	11253565.000
0.100	12458982.000

3

1. The flows are summed into volumes for the period of interest (typically April 1 – July 31)
2. The statistics are simplified
3. 50% exceedance value approximates the most probable forecast